THE TERRACES OF THE SWAN AND HELENA RIVERS AND THEIR BEARING ON RECENT DISPLACEMENT OF THE STRAND LINE.

By M. Aurousseau, B.Sc. (Sydney).
Lecturer in Geology, University of Western Australia,

and

E. A. Budge, B.Sc. (Tasmania).
Science Master, Guildford Grammar School.

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CONTENTS.

1. Physiography—
   (*a*) The segments of the Swan River
   (*b*) The Swan Coastal Plain
   (*c*) The Islands of Fremantle
2. Geology—
   (*a*) The crystalline plateau
   (*b*) The Guildford clays
   (*c*) Drift Sands
3. The Terraces and Levels
4. Notes on the profiles
5. The cycles of erosion
6. Correlation with the features of "uplift"
   (*a*) Of the Lower Swan
   (*b*) Of Rottnest Island
   (*c*) Of the Swan Coastal Plain
   (*d*) Of the Darling Escarpment
7. Summary and Conclusions
8. Literature
9. Explanation of Plates

Physiography.—Evidence of uplift has been produced from a number of widely separated places on the Australian coast. The Western Australian evidence has been summarised by Jutson (10), who, however, saw no direct indications of uplift in the Swan River District, though he had stated (9) that uplifts may have taken place. Woodward believed that uplift was in progress at Fre-

mantle (3), but did not produce adequate evidence to support his belief. Somerville has recently placed the matter beyond doubt (16), by recording and describing numerous features in the Perth District which are indisputable evidence of a recent displacement of the strand line, resulting in an apparent uplift of 23 feet from the present high water level. We considered that this movement should have been clearly recorded by the terraces of the Swan and Helena rivers, and, therefore, investigated the problem. Since the appearance of Daly's suggestive papers (18, 19), recent uplift has assumed world-wide importance, and we have attempted to apply the results of our work as a test of Daly's hypothesis. As great uncertainty now prevails in the use of the terms "elevation and subsidence of the land," "displacement of the strand line," and "eustatic movement of the ocean," we shall use the term "rejuvenating movement" when speaking of the recent changes of the Swan and Helena rivers.

The Swan and Helena rivers, having terraces developed above the tidal limit, and raised beaches below it, are similar to the Moonee River, Vic. (6), which has terraces associated with raised beaches. We suggest that the investigation of river terraces has an important bearing on the problem of eustatic movement.

The Segments of the Swan River.—Somerville (16) has divided the lower Swan into convenient physiographic segments, each of which has fairly uniform features. To these we add two further segments. From Burswood to Guildford, the river flows through a wide valley, the sides of which are obscured by recent sand dunes. This segment is transitional in nature, for here the more evident features of the lower segments, which are due to the drowning (9, 10), prior to the rejuvenating movements, give way to features usually ascribed to uplift. From Guildford to the foothills of the Darling escarpment, beyond Upper Swan, the river flows in a valley, which Jutson terms "precociously mature," and exhibits all the characters of a river which has reached maturity after several successive rejuvenations. The Helena joins the Swan at Guildford and is similar to the Swan, from where it also emerges from the escarpment, but has a slightly steeper gradient, and is, therefore, more juvenile.

The Swan Coastal Plain.—This prominent feature of the physiography of Western Australia has been adequately described by Jutson (10), in a broad way, while Woolnough has elaborated the description and recognises in it a series of distinct elements (15). We shall compare the features of rejuvenation existing in the Perth District with other features, further afield, which have not yet received detailed study, but may reasonably be ascribed to the same causes, especially if Daly's hypothesis be correct. The lakes marginal to the sea, between Bunbury and Mandurah, form a pro-

minent physiographic line, and their parallelism and serial arrangement call for an explanation which we believe is given by the rejuvenating movements which affected the Perth District. The explanation we shall give of the Rottnest lakes confirms our opinion concerning the Bunbury lakes.

The Islands off Fremantle.—Garden Island, Carnac, and Rottnest represent a former westward extension of the coastline, and were probably separated from the present coast by local subsidence (10). They are formed of Coast Limestone (a consolidated, carbonate dune rock) and of recent sand dunes. Rottnest, which encloses a group of salt lakes, gives very clear evidence of having been affected by rejuvenating movements.

The whole island is surrounded by a reef, or wave-cut platform, which extends for half a mile or more to sea, where it ends abruptly, being undermined by the waves. The solid reef limestone appears to rest on unconsolidated sands. At high tide it is covered by three to four feet of water off-shore, whence it shallows gradually to the shoreline, where it ends usually in a beach, or on headlands and exposed places, against low, undercut cliffs of limestone. It is the product of recent wave action, with a very low wave base, owing to the shallowness of the surrounding sea. The modern beaches are often bordered to landward by a low raised beach, indicating a movement of about eight feet. An older, elevated platform replaces the raised beaches on the rocky shores and stands about four feet above high water mark. There is also indication of a platform about twenty feet above high water mark, but owing to the rapid weathering of the coast limestones under wind and rain, and to the encroachment of recent dunes, this high-level platform is very obscure. Where recognisable, it often carries fragments of large shells upon its surface. One such platform exists at the northern end of Thompson Bay, and another extends from Nancy Cove to the Eastern end of Strickland Bay. The platforms are interpreted as elevated reefs.

The shores of the salt lakes expose a most interesting section composed almost everywhere of consolidated shell beds, which extend to greater heights than the present shores of the lakes, and end frequently against undercut limestone cliffs, the bases of which are about eight feet above high water mark. Elsewhere the shell beds extend far inland, marking former extensions of the lakes, as at the north end of Garden Lake. In a few places, the beds mark old shorelines at a greater height than eight feet, as at Padbury's Flat. The shells are very abundant, and are well preserved, the two valves of pelecypods often being united. The shells belong to existing species, and form a very different assemblage from that of the shell beds of Perth and Melville Waters. Associated with the Rottnest shells are one echinoid, one serpulid worm, and one

large foram. These beds show that the lakes were formerly less saline, and were connected with the sea. Their elevation above the present strand suggests that the closing of the lakes, and the union of two or perhaps three islands to form the present Rottnest, were effected by the rejuvenating movements. It also affords an explanation of the salinity of the lakes. The coast limestones are exceedingly porous, and the great loss of water from the lakes by evaporation during the hot and dry summer can only be counterbalanced by percolation of sea water through the limestone, which in turn implies continuous increase in salinity. The fresh water gained by the lakes during the wet winter is not competent, in our opinion, to maintain a balance with the sea. Two points of former union of the lakes with the sea are probable, one being at the eastern end of Government House Lake, leading into Thompson Bay, the other being at the site of the proposed canal at the northern end of Lake Bagdad. The drifting of sand bars and dunes and the rejuvenating movements combined, we believe, in closing the lakes, and evaporation balanced by percolation from the sea has rendered them saline. Both actions have caused the extinction of the shell fauna.

GEOLOGY.

The Crystalline Plateau.—The terraced segment of the Swan River is flanked on the east by the fault scarp of the Darling peneplain. The scarp has been described by Jutson (10), and the features of the uplifted peneplain by Woolnough (13). In the Guildford District, the plateau escarpment is composed of a variety of granites, which do not appear to show any clear marginal relationship to each other, one type grading imperceptibly into the next. They are believed to be Pre-Cambrian in age, and are penetrated everywhere by a plexus of basic dykes, here for the most part epidiorites, though dolerites are also known to occur. Further north, beyond Upper Swan, a gneissic series makes its appearance (9), but it has received little investigation.

The Guildford Clays.—The Swan itself flows over the Guildford Clays from Upper Swan to Guildford. This formation extends right up to the foot of the Darling escarpment, and is claimed by Woolnough as part of a continuous piedmont apron (15). This view seems to be fully justified, but the relationship of the Guildford clays are not entirely apparent. They have claimed attention since 1884, owing to their artesian water content. With their associated beds they form a distinct series, which we shall term the Guildford beds. They extend to a great depth, as is shown by the bore sections (8), and are of irregular character, without persistent horizons. They contain beds of hard sandstone in some places, but, as a rule, are not well consolidated. In lithological character they vary from red clays to sandy clays, gravels, sandstones, and

even to calcareous sands. In the railway cutting, on the north side of the Swan, at Upper Swan, they show signs of contemporaneous erosion. Lithologically they have been thoroughly described by Hardman and Nicolay (1, 2). Simpson refers to them as being of Mesozoic age (7). They afford no palaeontological evidence. Shells are found in the bore sections of the Perth District, but are absent from the Guildford bores (5). They are best considered as a piedmont deposit, post-dating the formation of the Darling escarpment.

Drift Sands.—The Western bank of the Swan, between Guildford and Upper Swan, is bordered at a varying distance by dunes which have been fixed by vegetation. The dunes belong to the coastal dune belt, but are here siliceous rather than calcareous. They represent the earlier accumulations during the period of coastal progradation, which preceded the cycle of drowning referred to previously (10). All the rivers of the Swan Coastal Plain appear to be consequent upon the Darling escarpment, but the encroachment of the dunes has had a powerful effect in deflecting the streams on the plain (10), and the Swan has been forced, in the Guildford District, to take a subsequent course over the Guildford beds, until, by gathering strength from the Helena and the Canning, it has attained supremacy over the dunes. The surface of the Guildford beds slopes gently to the south, but the western gradient, on the western side of the Swan, is sufficient to cause stagnation of the drainage from the high dunes, with the result that a number of swamps have formed between the dunes and the river.

The Terraces and Levels.—In order to investigate the terraces four lines of levels were determined by theodolite, crossing the valleys of the Swan and Helena (the latter in two cases only), approximately at right angles. From the levels obtained, profiles were plotted on a uniform scale, and these, combined with an examination of the ground, have led us to our conclusions. Four physiographic levels have been clearly revealed, and a fifth is believed to exist, but is not so well marked nor so well preserved as the remainder. The uppermost level is that of the surface of the Guildford beds, the lower levels being indicated by river terraces. As the terraces are developed symmetrically in both rivers, and correspond very closely, they are of the type usually ascribed to uplift (11).

The uppermost, or *Caversham level,* is the original erosion surface of the district. It has an elevation of 44 feet above survey datum at Guildford and Midland Junction, and slopes very evenly upwards to the north, being 70 feet above survey datum at Upper Swan. In this level the Swan and Helena eroded their original paths over the Guildford beds, and developed broad and precociously mature valleys until the close of the cycle of drowning. The thalweg so formed constituted the *Guildford level,* which is now

represented by a well marked terrace in both valleys. It is very well developed at the Old Golf Links on the northern side of the Swan at Guildford. The Guildford level is traceable almost continuously for a long distance up both valleys. At Guildford it is 13 feet below the Caversham level in the valley of the Swan, and seven feet below it in the valley of the Helena—a nice expression of the relative powers of the two rivers. At Albion Town north of Herne Hill it is nine feet below the Caversham level, and at Upper Swan it is very feebly developed. It is here represented by obscure shoulders on the Caversham slopes, and we estimated its depth by diagrammatic means to be only five feet below the Caversham level. It is, however, quite traceable in the landscape. The Guildford level therefore rises towards the Caversham level proceeding upstream. This is what would be expected during a period of stillstand, or of slow subsidence (4). Rejuvenating movement now supervened, and the soft Guildford beds became entrenched below the Guildford level, leaving it as a river terrace. This first phase of the rejuvenation is marked by distinct remnants of a once continuous terrace in both valleys, but the new thalweg which it represents as having developed below the Guildford level has been greatly obscured by the subsequent development of the rivers. This third level is clearly shown to the south of West Midland railway station, in the valley of the Helena, and we have named it the *West Midland Level*. At Guildford the West Midland level is eight feet below the Guildford level in the Swan Valley, and 10 feet below it in the Helena. Again we have a response to steeper grade in the Helena. At Albion Town this level is 30 feet below the Guildford level, and at Upper Swan is 31 feet below it. The level is easily traceable in the scenery, and we are not in doubt about its identification. We are here dealing with the effect of the steady and continuous increase in the corrasive power of the Swan under the influence of rejuvenation, and as this power increases by "compound interest" in proceeding up a normal stream from its mouth, the relative increase in corrasive power under rejuvenating influences is very much greater than in the normal condition. The rule may be restated that *levels due to rejuvenation will diverge from the older levels of stillstand or subsidence in proceeding upstream.* (c.f. 4.) In other words, the further we go towards the head of the Swan, the greater will be the vertical interval between the Guildford and the West Midland levels (terraces).

The West Midland level only marks a pause in the process of rejuvenation. When the movement started again further entrenchment took place, the second pause being recorded clearly in the Helena but less distinctly in the Swan valley. At Guildford, seven feet below the West Midland terrace, in the Helena valley, is another terrace which we believe records a fourth level. At the Old Golf Links at Guildford, in the Swan valley, is a lower platform which

corresponds to this level, and at Albion Town there is a terrace greatly dissected by ox-bows, standing five feet below the West Midland level. Other features to be considered render it extremely probable that a true level exists in this position, and that we are not dealing with accidental terraces. We have named the fourth level the *Helena Level.* When the width of the present valleys is considered, the presence of clear and continuous records of the Helena and West Midland levels is seen to be impossible. The Swan now meanders in a valley as wide as that of the Guildford days.

The lowest level is that of *the present flood plains.* At Guildford the present flood plain of the Swan is 15 feet below the West Midland level. At Albion Town the distance has not increased, but at Upper Swan it rises to 18 feet. The depth of the Helena flood plain below the West Midland level is 13 feet in the western profile and 11 feet in the eastern, the distance between the two being only half a mile. In both cases it is well above the flood plain of the Swan, indicating the steeper gradient of the Helena.

The significant inference from the foregoing details is that the total intervals due to rejuvenation (Guildford to present levels) in both rivers in the Guildford District are of the same order, that is, about 22 feet, as indicated by the profiles. Now, as a corollary to the previous rule, we state that *the intervals between river terraces due solely to rejuvenating movements will be equal to the actual amount of displacement only in the vicinity of base-level.* But the maximum "uplift" recorded by Somerville is 23 feet (16). We conclude, therefore, that the river record of the Guildford District is an actual measure of the rejuvenating movement, and that Guildford was near base-level. Jutson states correctly (9) that the Swan is affected by the tides as far as Guildford at the present day.

The levels should prove useful in the study of rates of erosion if Daly's hypothesis be proved ultimately to be correct, as the terraces are dissected by innumerable brooks the ages of which can be gauged accurately. Sub-surface drainage (14) was observed at Upper Swan.

Notes on the Profiles.—Profile No. 1 shows the Caversham, Guildford, West Midland, and Present levels in the Swan valley, the West Midland level being here slightly truncated. Guildford itself is on a remnant of the Caversham-Guildford slope. In the Helena Valley the Caversham, West Midland, Helena, and Present levels are shown. Profile No. 2 shows the same levels as No. 1 for the Swan, the West Midland level being again truncated. In the Helena, the Guildford, West Midland, and Present levels appear. Both of these profiles were brought into line with survey datum by tying the traverse on to a railway bench mark. Profile No. 3 (near Albion Town) shows an encroachment dune on the west, and the Caversham,

Guildford, West Midland, Helena (?), and Present levels. From Susannah Brook to the east this profile was completed by inspection of the ground, not by theodolite levelling, owing to lack of time and a failing light. The levels observed were corrected to survey datum by the height of Herne Hill siding, which is on the Caversham level (17). Profile No. 4 (at Upper Swan) shows the Caversham, Guildford (obscurely), West Midland, and Present levels, and an intermediate terrace between the Guildford and West Midland levels. The last is interpreted as a stiff-off terrace (11), a type likely to be encountered upstream where corrasive power is at its height. The West Midland level was identified with certainty by plotting the gradients of the levels to scale on squared paper, which rendered its harmony with the system apparent. As with No. 3, this profile was co-ordinated with survey datum from the height of Upper Swan Siding (17), which is also on the Caversham level. Profile No. 5 is an idealised representation of the levels as shown by both rivers. Profile No. 6 shows the gradients of the levels along the course of the Swan, and, like Nos. 3 and 4, gives a very clear idea of the divergence of the levels due to rejuvenation, and of their convergence during stillstand or subsidence in upstream sections. It was by means of this diagram that the truncation of the West Midland terrace in the Guildford District was first recognised.

The heights of the levels for the various profiles are tabulated below. The levels are numbered in descending order of age; heights are stated in feet.

		Guildford.				Albion Town.	Upper Swan.
	—	Helena.		Swan.		Swan.	Swan.
		a.	b.	a.	b.		
1	... ...	44	44	44	44	62	70
2	... ...	...	37	29	29	53	65 ?
3	... ...	25	25	21 ?	21 ?	23	32
4	... ...	18	...	...	...	18	...
5	... ...	12	16	10	8	8	11

The Cycles of Erosion. It will be conceded that the interval between two succeeding and persistent levels indicates a cycle of erosion. The levels here recognised correspond to four such cycles. The first, or *Guildford cycle*, represents the difference between the Caversham and Guildford levels, and was the initial cycle. It was a period of subsidence followed by stillstand (the drowning referred to by Jutson and Somerville). The interval between the Guildford and West Midland levels, or *West Midland cycle*, was a period of rejuvenation. After a pause the *Helena cycle* was initiated, we believe with further rejuvenation. After a second pause the *Present cycle* was ushered in with rejuvenation, which has now given place to stillstand. The amounts of entrenching done during these cycles

are given below for comparison with the previous table. The cycles of erosion are numbered in descending order of age. The figures represent differences in feet between succeeding levels. Queries to figures indicate a possible error of a foot, while queries alone indicate that the necessary levels are not developed in the particular profile.

	Guildford.				Albion Town.	Upper Swan.
	Helena.		Swan.		Swan.	Swan.
	a.	b.	a.	b.		
1	?	7	15	15	9	5 ?
2	?	13	8 ?	8 ?	30	33 ?
3	7	?	?	?	5	?
4 ... / 1 ...	6	?	?	?	9 ?	?
2 ... / 2 ...	19	19	23 ?	23 ?	39	39 ?
3 ... / 3 ...	?	?	?	?	35 ?	?
4 ... / 2 ...	11	?	?	?	14 ?	?
4	?	22	21 ?	21 ?	44	53

Correlation with the Features of "Uplift."—The differences in height between the levels of rejuvenation in the Guildford District (believed to have been in the vicinity of base-level throughout), and the amount of movement indicated, are tabulated below:—

Levels.	Difference in Height.	Movement.
	ft.	ft.
Guildford to West Midland...	8	8
West Midland to Helena	7	15
Helena to Present	7	22

In the *Perth District and the Lower Swan* the details of the features of uplift described by Somerville (16), if tabulated, are found to fall into three clearly marked groups, their heights above present high water level lying between the following limits:—

First Group	1ft. to 7ft.
Second Group	7ft. to 15ft.
Third Group	15ft. to 23ft.

The reader is referred to Somerville's figures and map for the details. Now, it seems evident from the above tables, that the cycles of erosion which we have defined are expressed further afield, and we correlate the third group of the features Somerville has described with the West Midland cycle. This will include the shell beds of Minim Cove and Peppermint Grove, the "raised" beach and shell beds of the Coombe, the "raised" beach of Blackwall Reach, the Crawley-Nedlands "raised" spit, and (though not described by

Somerville) the very evident higher level of the South Perth "raised" shoal, the levels of which can be clearly discerned from the junction of Labouchere Road, Lyall Street and Mends Street.

The second group corresponds to the Helena Cycle, and includes the shell beds of Hinemoa Rock, Mosman's Bay, some of the higher shell beds at Cottesloe Beach, and the "raised" spits of Points Roe and Preston, and of Peppermint Grove. The striking difference noticed by Somerville between the assemblages of shells in the beds of Mosman's Bay and Minim Cove has therefore a partial explanation if the cycles of rejuvenating movements be accepted.

The first group falls into the Present Period, and embraces the lower shell beds of Cottesloe Beach, and the associated "raised" platforms, part of Mill Point Spit, and the numerous "raised" beaches to be observed around the foreshores, at low elevations above high water mark. The last features have not been described in detail by Somerville, but are well developed, as, for instance, at Mends Street Jetty and at Applecross. These low "raised" beaches often bear a ti-tree and swamp flora.

A most important formation, if eustatic movement is to be demonstrated, exists in the hidden shell banks of Perth and Melville Waters. These beds are covered by recent sand and mud, but are frequently revealed in dredging operations, and are so rich in shells that they are used extensively for road making and reclamation. A number of different species have been collected by Dr. E. S. Simpson, and determined by Mr. C. Hedley of the Australian Museum, Sydney. Ostrea Angasi is the most abundant species. These shells are of the greatest interest, but we do not wish to anticipate Dr. Simpson or Mr. Hedley in the description of the formation, though it is necessary for our purpose to make some reference to it. None of the species is now existent in the neighbouring waters, the river indeed being almost devoid of molluscan fauna. We correlate the *Perth Shell Banks* with the Guildford Cycle, and believe them to be antecedent to the rejuvenating cycles. During the Guildford cycle the Swan broadwaters were much more extensive than they are now. The effect of rejuvenation was to restrict the volume of the broadwaters, and to render the get-away of the winter floods more difficult owing to local constrictions of the channel, especially at the Narrows. The accelerated silting, and lowering of salinity which ensued assisted in extinguishing the fauna. The shells themselves, however, indicate also an important climatic change which is a necessary postulate in Daly's hypothesis (18, 19). At *Rottnest Island* we correlate with the West Midland cycle the obscure high level platforms. To the Helena cycle are assigned the *Rottnest Shell Banks* of the salt lakes, and their associated undercut cliffs and elevated strand lines. It is possible that some of the

more elevated shell beds and shore lines belong to the preceding cycle, but this cannot be demonstrated without careful levelling. The Rottnest shell banks are as important in our local geology as are the Perth shell banks. Shells from the Rottnest banks have also been examined by Mr. Hedley, who states that they belong to existing genera, and indicate a climate similar to the present one of the locality, whereas those of the Perth banks indicate warmer conditions. The closure of the lakes, and the union of two or perhaps three islands to form the present Rottnest may be assigned to the close of the Helena cycle or to the opening of the Present period. The striking fact for the visitor is that the inderent cliffs of the salt lakes belong clearly to Helena times, while those of the sea shores belong equally clearly to the present period. In the absence of careful levelling, confusion also exists concerning the "raised reefs" and "raised" beaches of the present sea shores, which belong to the borderline between the two cycles. The existing reef platforms and the inderent shores of course are definitely products of very recent action.

"Uplift" has been demonstrated at widely separated places on the shores of the *Swan Coastal Plain*, but it is not our intention to deal with regional movement here. The whole question of recent "uplift" around the shores of Australia shall be reviewed by one of us (M.A.) shortly. The lakes marginal to the sea, between Bunbury and Mandurah, have been mentioned on a previous page, and shall be considered briefly. Leschenault Inlet, Lake Preston, the Martin Tank line of lakes and swamps, and Lake Clifton are long, narrow sheets of water arranged in echelon parallel to the coast. Leschenault Inlet is connected with the sea. Lake Preston is not, and is saline, and is associated with a development of the Rottnest shell banks. The Martin Tank line has an elevation of about 35 feet above sea level and is associated with a development of the Perth shell banks (*fide* Mr. A. E. Mitchell, B.Sc.). Lake Clifton, still further inland, stands about 60 feet above sea level. The sequence of events in this area seems to have been similar to that of the Swan River District, with this exception: that instead of a cycle of drowning prior to the rejuvenating movements there was here an actual uplift in pre-Guildford times, which elevated Lake Clifton. The Martin Tank line, with the associated Perth shell banks, are interpreted as the product of the Guildford cycle. Their present height above sea level is not in accordance with eustatic movement unless it be assumed that the movement of uplift was also still in progress. Lake Preston and its Rottnest shell banks we assign to the Helena cycle, and Leschenault Inlet to the Present period. We suggest that each of these lakes has been closed and rendered saline by processes similar to those which operated on the lakes of Rottnest Island.

One of us (M.A.) considers that the larger brooks issuing from the *Darling Range Escarpment* in the Swan River District show distinctly younger valley profiles in the lower parts of their courses than further upstream. As examples Jane Brook, and Narrogin Brook (Armadale), are quoted. This feature is connected with the whole period of rejuvenation. It is necessary, however, to bring to notice the factors which may assist or retard corrasion in these streams.

Corrasion may be assisted by the jointing and faulting of the crystalline plateau. Jointing is difficult to trace, but might be expected to have been recorded by a yielding formation such as the Armadale shales. The joint systems of this formation have been plotted, and are found to belong to two series, each having two sets of joints at right angles, showing in all twelve separate directions.

First series—
- Set a .. N.N.E. by N. to S.S.W. by S.
- Set b .. E.S.E. by E. to W.N.W. by W.

Second series—
- Set a .. E.N.E. by N. to W.S.W. by S.
- Set b .. N.W. by N. to S.E. by S.

The former series is the stronger, but none of these directions seem to be prominently marked in the drainage of the plateau. Faulting is more easily recognised. From an examination of the Armadale District, we conclude that the Narrogin Brook and its northern tributary follow a line of fault behind the foothill zone (15), having found a displacement of laterite level in this zone, amounting to about 200 feet, on the south side of the Canning Valley. Laterite displacement of this amount is a clear indication of recent faulting (12). A similar displacement has also been observed between Jane Brook and its northern tributary well within the Range, and the course of Jane Brook behind the foothills zone resembles that of Narrogin Brook. It is suggested that *the foothill zone is always a product of step faulting.*

Factors which may assist in the development of local maturity are of the nature of temporary base-levels. The only competent obstacles are the basic dykes. From a careful study of their outcrops we believe that *the basic dykes are more easily weathered, but less easily eroded, than the granites* of the district. The difference in both cases is very slight. Where a dyke crosses a hill at right angles to the contours it weathers out, leaving a col. Lower down the hillside the same dyke forms a ridge, for here erosion is more rapid than weathering. Similarly, where a dyke is parallel to or inclined to the contours at a low angle, the outcrop forms a distinct ledge on the hillside. So far, however, we have not seen a dyke which has become an obstacle or temporary base-level for a stream.

CORRELATION TABLE.

Cycle.	Guildford District.	Perth District.	Rottnest.	Bunbury-Mandurah.	Darling Range.
Pre-Guildford ...	Subsidence and Still-stand. Caversham Level. Dunes and Marshes	Subsidence. Dunes	Coast Limestone. (Subsidence.)	Uplift. Lake Clifton	Piedmont Plain. Mature upper parts of small streams.
Guildford. Climate warmer than at present	Guildford Level (terrace)	Perth Shell Banks.		Martin Tank line. Perth Shell Banks.	
West Midland ...	West Midland level (terrace). Rejuvenation.	Minim Cove Beds. Peppermint Grove Beds. Beach at The Coombe. Beach at Blackwall Reach. Crawley Spit. Part of S. Perth	High Level platforms.		
Helena. Climate similar to present day	Helena Level (terrace) Rejuvenation	Shell Beds at Hinemoa Rock, Mosman's Bay, Cottesloe Beach. Spits at Pts. Roe and Preston, Peppermint Grove	Rottnest Shell Banks. Raised shores and undercut cliffs of Lakes. Closing of Lakes. Raised Reefs	Lake Preston. Rottnest Shell Banks.	
Present	Flood Plains. Rejuvenation.	Shell Beds at Cottesloe Beach, Mill Pt. Raised Beaches of present shoreline	Rottnest Island. Existing reefs. Undercut cliffs of sea shore	Leschenault Inlet.	
Whole period of Rejuvenation	...	Sediments above the Perth Shell Banks	...	...	Rejuvenated lower parts of small streams.

SUMMARY AND CONCLUSIONS.

(1.) The Swan and Helena Rivers have recorded four cycles of erosion, which are marked by river terraces. The first cycle was one of stillstand in the Guildford District. The second, third, and fourth cycles were caused by rejuvenating movements, indicating an uplift of the land or a sinking of sea-level of 22 feet.

(2.) The climate of the district was warmer before the movement than it is now. This is indicated by two important formations, the older Perth Shell Banks, and the younger Rottnest Shell Banks.

(3.) The amount of movement is the same as that described as being due to "uplift" in the Perth District (23 feet).

(4.) Various physiographic features in the Perth District, at Rottnest Island, in the Bunbury-Mandurah District, and in the Darling Range east of Perth can be correlated easily with the four cycles of erosion, which may therefore be taken as the local basis for the subdivision of Recent Time.

(5.) In Pre-Guildford time actual subsidence was taking place in the Swan River District, while uplift was in progress further south in the Bunbury-Mandurah District.

(6.) The evidence of recent changes in the Swan River District supports Daly's hypothesis of a recent world-wide sinking of ocean level.

In collaborating on this paper we desire to state that the following partition of work was made. The theodolite levelling and construction of the profiles were carried out by E. A. Budge, and the general field work and correlation were done by M. Aurousseau. We also wish to thank our students Messrs. Calder and Thorburn, of the Guildford Grammar School, and Messrs. Cummins and Worboys, of the University of Western Australia, for assistance in the field work.

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EXPLANATION OF PLATES.

Plate I. ... ... The Helena Valley, looking South from Guildford, A, on map. Shows anabranches, and terraces in the distance. E.A.B. photo.

Plate II. ... ... The Swan Valley, looking North from Mr. Harper's house. B, on map. Shows width of present flood plain, and terraces in distance. E.A.B. photo.

Plate III. ... The Swan Valley at Upper Swan. C, on map. Shows present flood plain, Caversham level (house on skyline), slip-off terrace (behind haystack), and West Midland level (in front of haystack). M.A. photo.

Plate IV. ... ... The Guildford beds and Darling Range, from Upper Swan. D, on map. M.A. photo.

Plate V. ... ... The Rottnest Shell Banks. Between Garden Lake and Lake Herschell, Rottnest. M.A. photo.

Plate VI. ... ... Present Marine abrasion at Rottnest. Undercut limestone West of diving pool. The man is standing on the reef. M.A. photo.

Plate VII. ... Map of the Guildford District.

Plate VIII. ... Profiles (to scale) of the Valleys of the Swan and Helena Rivers.

Plate I.—The Helena Valley, looking South from Guildford.

Plate II.—The Swan Valley, looking North.
(B. on Map.)

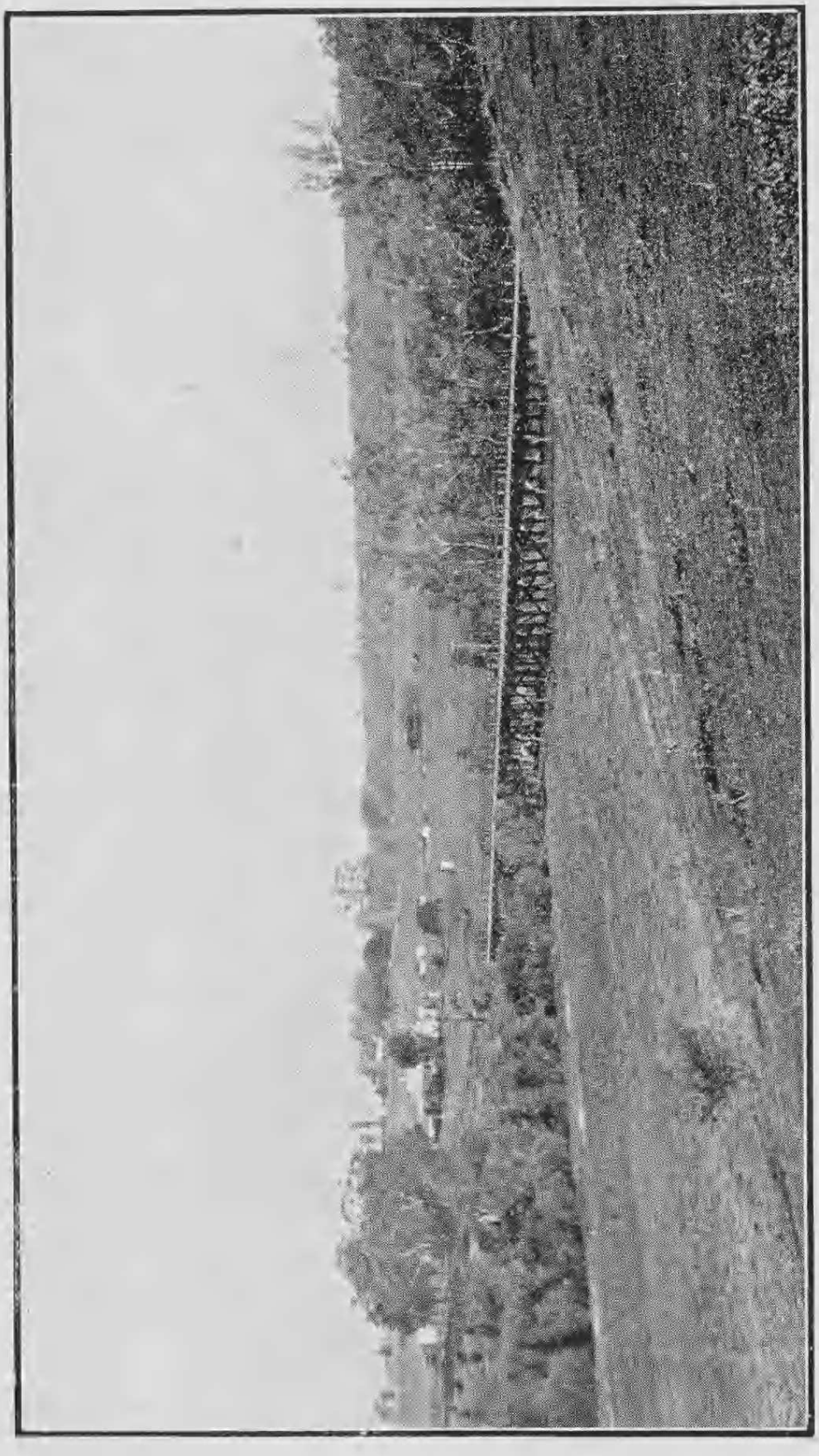


Plate III.—The Swan Valley at Upper Swan. (C. on Map.)

Plate IV.—The Guildford Beds and Darling Range from Upper Swan. (D. on Map.)

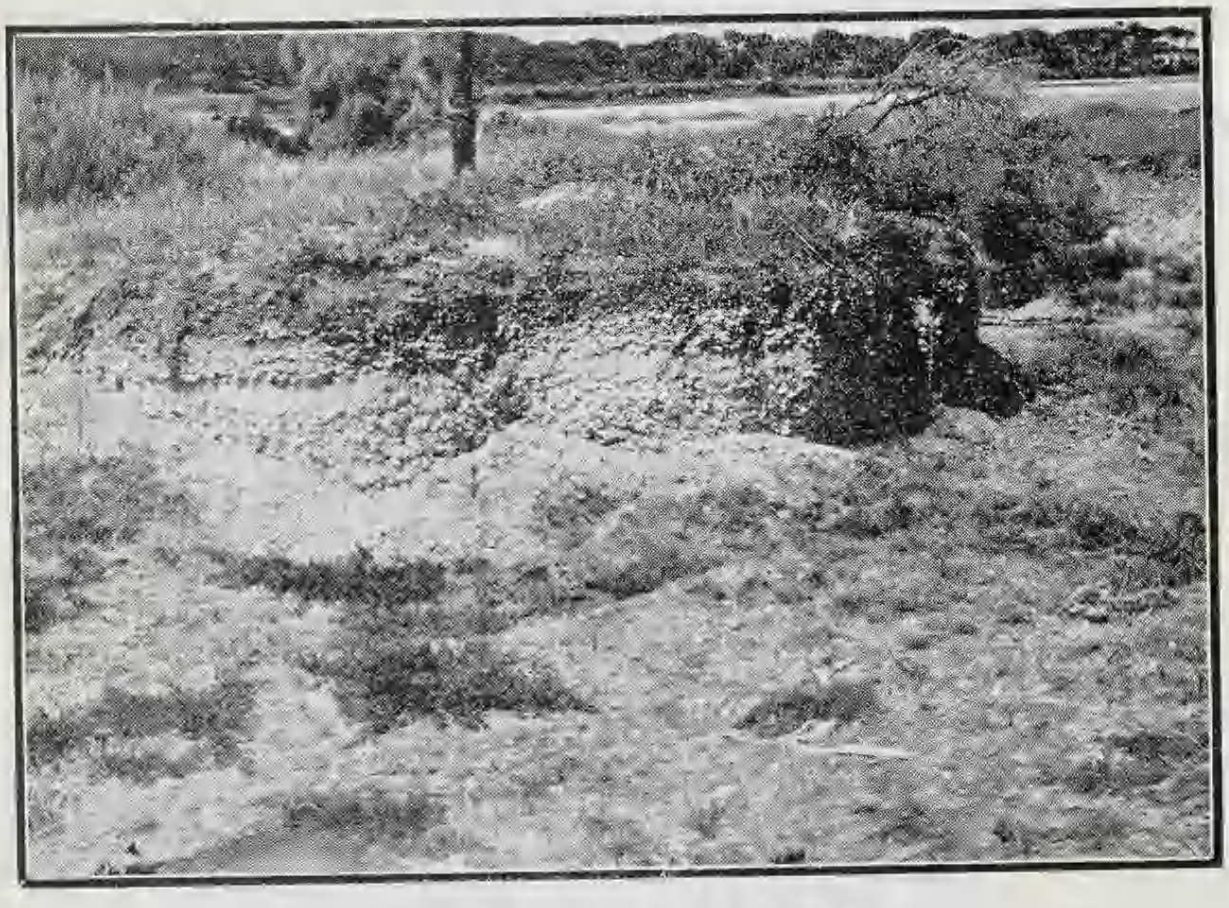
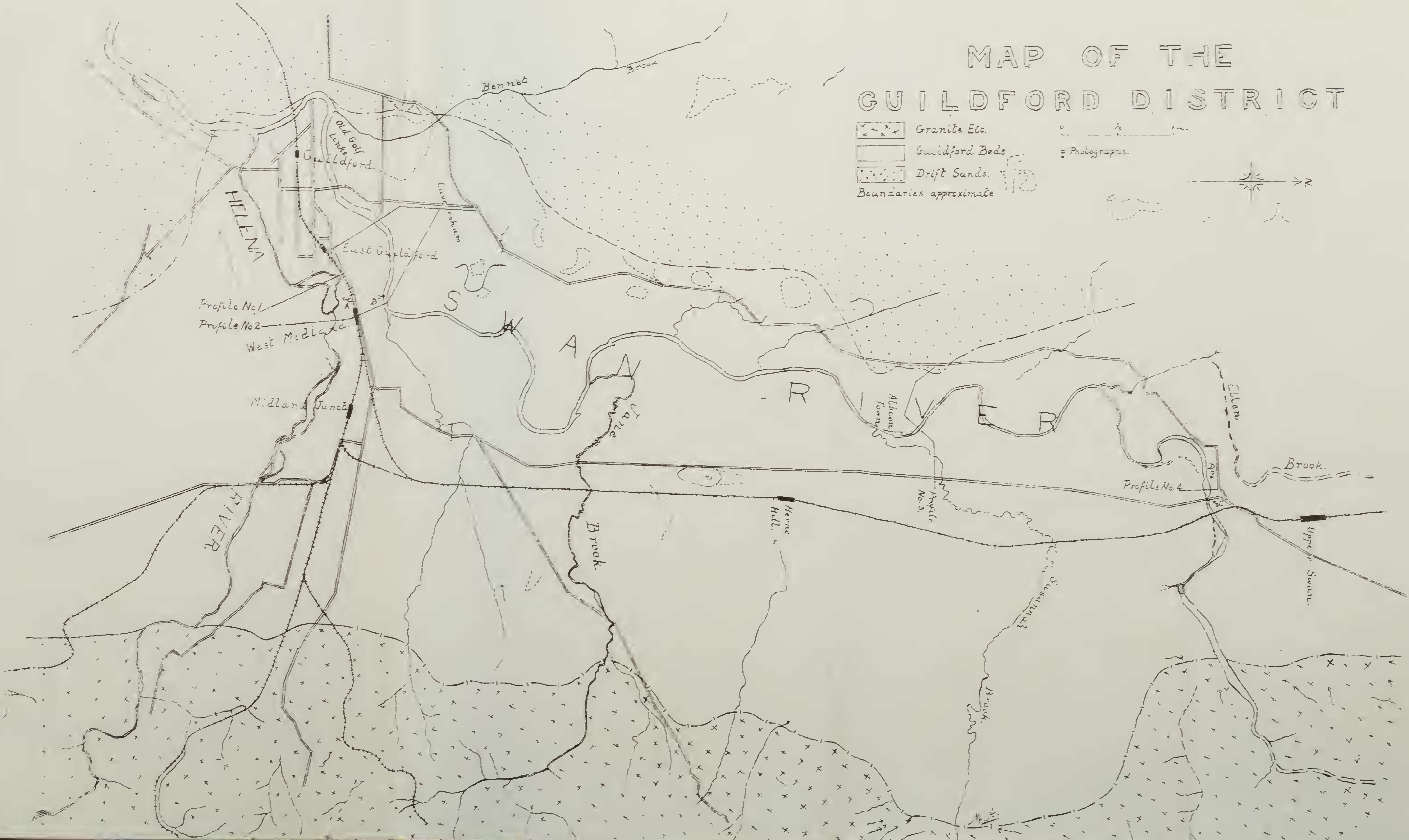


Plate V.—Rottnest Shell Banks.



MAP OF THE
GUILDFORD DISTRICT
Granite Etc.
Guildford Beds
Drift Sands
Boundaries approximate
Photographs.
Bennet Brook
Old Golf Links
Guildford.
East Guildford
HELENA RIVER.
SWAN RIVER
Profile No.1
Profile No.2
West Midland.
Midland Junct.
Jane Brook.
Herne Hill.
Albion Town.
Profile No.3.
Profile No.4
Ellen Brook.
Upper Swan.
Susannah Brook.